

Q 43: Ultracold Molecules (with MO)

Time: Thursday 10:30–12:00

Location: E 001

Group Report

Q 43.1 Th 10:30 E 001

Ultracold chemistry and dipolar collisions in a quantum gas of polar KRb molecules — ●SILKE OSPELKAUS^{1,2}, KANG-KUEN NI², MARCIO DE MIRANDA², BRIAN NEYENHUIS², DAJUN WANG², JUN YE², and DEBORAH JIN² — ¹Max-Planck-Institut für Quantenoptik, Garching — ²JILA, NIST & University of Colorado, Boulder, USA

Polar molecular quantum gases promise to open new scientific frontiers and research directions. Due to their large electric dipole moment, polar molecules interact via long-range and anisotropic interactions. The control of these interactions provides unique opportunities ranging from the control of ultracold chemical reactions, applications to quantum information processing, novel strongly correlated quantum many-body systems to collisional control on the quantum level with external electric and magnetic fields. Here, we report on our recent experiments with a quantum gas of fermionic polar 40K87Rb molecules. We report the preparation of a near-quantum degenerate gas of rovibronic ground state molecules in a single hyperfine state and in particular in the absolute lowest quantum state - implementing full control over all internal molecular quantum degrees of freedom (electronic, vibrational, rotational and hyperfine). We discuss experimental evidence for chemical reactions at ultracold temperatures and show that simple quantum mechanical rules such as quantum statistics, single scattering partial waves, and quantum threshold laws provide the basis for understanding of the molecular loss rates at ultracold temperature. Finally, we report the observation of dipolar collisions in the polar molecular gas.

Q 43.2 Th 11:00 E 001

Enhancement of Photoassociation to Create Ultracold Molecules — ●RUZIN AGANOGLU, MAMADOU NDONG, and CHRISTIANE PIA KOCH — Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Ultracold molecules can be created coherently by shaped ultrashort laser pulses. Since the broad bandwidth of femtosecond pulses addresses both atomic and molecular transitions and atomic excitation leads to trap loss, the spectral amplitude of the pulse at the atomic resonance frequency needs to be completely suppressed. This is most easily achieved by cutting off the pulse amplitude at the atomic resonance frequency and higher spectral components [1]. However the process leaves then most of the pulse idle. Here a two-photon photoassociation scheme is suggested to drive the desired narrow transition with a broad-band laser. Local control theory is used to define conditions on the pulse such that atomic transitions stay dark while molecular transitions are excited. Moreover to increase the initial pair density at inter-nuclear distances where the photoassociation probability is high, the concept of non-resonant field control [2] is combined with shape resonances. [1] A. Merli et al., Phys. Rev. A 80, 063417 (2009) [2] M. Lemeshko and B. Friedrich, Phys. Rev. Lett. 103, 053003 (2009)

Q 43.3 Th 11:15 E 001

Effect of molecular structure on the stabilization of ultracold molecules — ●MAMADOU NDONG, FABIAN BORSCHTEL, and CHRISTIANE P. KOCH — Institut für Theoretische Physik, Freie Universität Berlin, Germany

Ultracold molecules are created from ultracold atoms using Feshbach resonances or photoassociation. As a result, the molecules are vibrationally highly excited. They can be stabilized by transferring them to their vibrational ground state via STIRAP or with optimally shaped pulses.

Using optimal control theory, we investigate the effect of the long-range behavior of the excited state potential, spin-orbit coupling and singlet-triplet mixing on the energy and the spectral range of the optimal pulse that performs the stabilization. We present a detailed study of the role of the long-range behavior of the excited state potential comparing Na₂ and KRb. Moreover, the spin-orbit coupling interaction for KRb is taken into account to study effects of resonant coupling and singlet-triplet mixing.

Q 43.4 Th 11:30 E 001

Population redistribution of vibrational ground state levels in ultracold polar molecules — ●JOHANNES DEIGLMAYR^{1,2}, MARC REPP¹, OLIVIER DULIEU³, ROLAND WESTER², and MATTHIAS WEIDEMÜLLER¹ — ¹Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — ²Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — ³Laboratoire Aimé Cotton, CNRS, Orsay

Recently we achieved the formation of LiCs molecules in the lowest levels of the ground state [1]. Polar molecules like LiCs can show strong long-range and anisotropic interactions, which makes ultracold dense gases of such molecules ideal systems for quantum information or the study of new quantum phases. However a large permanent electric dipole moment also leads to a stronger coupling of the internal molecular state to the environment via black-body radiation (BBR). Here the influence of BBR-driven transitions and spontaneous decay on the distribution of populated levels is investigated numerically for the ground states of LiCs and KRb using accurate potential energy curves and transition dipole moments. We will show experimental evidence for the occurrence of such redistribution processes in a sample of ultracold LiCs molecules. The molecules are formed by photoassociation and trapped in a quasi-electrostatic trap. State-selective detection of the molecules reveals population dynamics on time-scales which are in agreement with our theoretical model.

[1] J. Deiglmayr *et al.*, Phys. Rev. Lett. 101, 133004 (2008)

Q 43.5 Th 11:45 E 001

All Optical Rovibrational Ground State Preparation of HD⁺ Ions — ●TOBIAS SCHNEIDER, BERNHARD ROTH, HANNES DUNCKER, MICHAEL HANSEN, INGO ERNSTING, and STEPHAN SCHILLER — Heinrich-Heine Universität Düsseldorf, Universitätsstrasse 1, 40225 Düsseldorf

One important prerequisite for quantum measurements on molecules is the ability to control their translational as well as internal degrees of freedom. For molecular ions stored in an ion trap the motion of the molecules can be cooled via sympathetic cooling with laser cooled atomic ions. Cooling of the internal degrees of freedom is more difficult since in non-cryogenic environments interaction with black body radiation will generally distribute the molecular population over several ro-vibrational states.

We present a two laser optical pumping scheme suitable in principle for many types of diatomic molecules that allows to transfer most molecules to the ro-vibrational ground state. As a demonstration we apply the scheme HD⁺ molecular ions: Optically pumping with two cw lasers driving the ($v = 0, N = 2$) → ($v = 1, N = 1$) transition at 5484 nm and the ($v = 0, N = 1$) → ($v = 2, N = 0$) transition at 2713 nm of the electronic ground state, we increase the fractional ground state population from 10% to 78(4)% which is close to the maximum of 92% predicted by numerical simulations for a room temperature environment. A detailed analysis of the experiment and of the theoretical modelling of the pumping scheme will be given.